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Title: Fieldable Impulsive Source and Timer (FIST)

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Fieldable Impulsive Source and Timer (FIST)

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1. Overview

This document describes the Fieldable Impulsive Source & Timer (FIST). The key features of FIST are:

1.1. All-in-one carrying case, total weight < 20 lb
1.2. Portable self-contained battery-operated unit for outdoor use
1.3. Low-power short duration impulsive signal to stimulate a device under test (DUT)
1.4. Output timing controlled by a GPS receiver with auxiliary trigger output

Major features and characteristics of FIST are summarized in Table 1.

Name	Basic Characteristics	Operation
FIST	• Battery operation • Integrated GPS receiver to provide timing discipline • Custom Los Alamos built impulse generator (pulser) • Pulse characteristics ▪ Pulse duration ~ 3 μs; Pulse repetition rate <= 1Hz ▪ Frequency: 1-40 MHz ▪ Peak voltage < 2kV; Stored energy < 10 mJ ▪ Peak power (averaged during impulse period) ~ 3 kW • Primary pulse coupling mechanism ▪ Conductive low-impedance cable to the grounding point of DUT • Secondary pulse coupling mechanism ▪ Whip antenna with characteristics frequency ~ 30 MHz ▪ Radiation pattern: horizontal toroid; estimated antenna gain: 1 ▪ Estimated peak power at 10 km < 3 $\mu W/m^2$ ▪ 0.1-s average power at 10 km < 100 pW/m^2 broadband	• Portable outdoor • DUT operation check • DUT timing check

Table 1. Summary of FIST features and output, including potential RF emission

2. FIST Major Components

The FIST consists of mostly commercial-off-the-shelf (COTS) parts.

2.1. Carrying case,
2.2. Battery-operated GPS receiver and peripherals,
2.3. Impulse generator (pulser), and
2.4. Interface and coupling cable/antenna

Figure 1 shows the layout of these major components in the FIST carrying case. Contact the Los Alamos FIST team for a complete parts list.

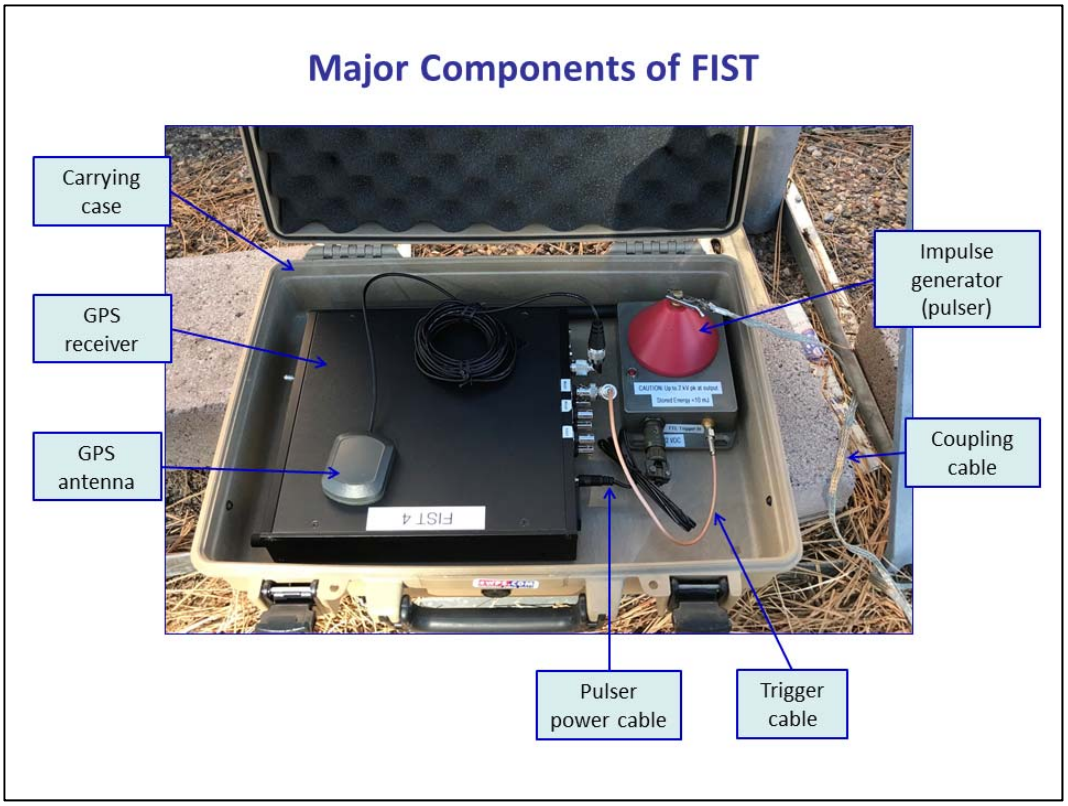

Figure 1. Major components and layout in the FIST case.

3. Output Assessment of FIST

3.1. Energy output/safety

3.1.1. The stored energy in the FIST per pulse is limited to < 10 mJ.
3.1.2. Typical energy content of an electrical static discharge is tens of mJ.
3.1.3. This unit is within the safety envelope of low-hazard electrical device defined in Los Alamos National Laboratory electrical safety standard.
3.1.4. FIST is designed to be used by trained and authorized personnel. It should not be used on or near sensitive electronics devices susceptible to electrical static discharge damage.

3.2. Radiated emission

3.2.1. FIST is designed to be used in close proximity to the DUT. Primary impulse injection is through conductively coupled low-impedance cable to the DUT's grounding network. FIST does have a secondary coupling mechanism through an antenna, designed for portability and not for efficiency.
3.2.2. Assuming a perfect antenna, the FIST's radiation characteristics are as follows.
3.2.2.1. Impulse is ~ 3 μs in duration.
3.2.2.2. Impulse is between 1-40 MHz.
3.2.2.3. Estimated peak power is < 3 $\mu W/m^2$ at 10 km distance.
3.2.2.4. Estimated average power is < 100 pW/m^2 at 10 km distance over 0.1 second, following FCC's impulsive source calculation methodology.

3.2.3. For comparison, other known manmade and natural persistent or transient RF radiation sources include the following.

3.2.3.1. KKOB 770AM radiates 50 kW at 770 KHz. This narrow band (<20 kHz wide) CW signal level is 40 $\mu W/m^2$ at 10 km distance.

3.2.3.2. KUNM 89.9FM radiates 21.5 kW at 89.9 MHz. The CW signal level is 18 $\mu W/m^2$ at 10 km distance.

3.2.3.3. KOAT Channel 7 broadcasts digital signals at 26.5 kW between 174 & 180 MHz. The digital signal level over the 6MHz bandwidth is 21 $\mu W/m^2$ at 10 km distance.

3.2.3.4. Natural RF transient background: Typical lightning's peak power is estimated to be TeraWatt (10^{12}W) for about 30 μs (http://en.wikipedia.org/wiki/Lightning), mostly as dissipated heat. A lightning stroke is estimated to impart an RF transient with a peak radiated power of ~10 mW/m^2 at 10 km distance.

3.2.4. Summary & Conclusion

3.2.4.1. FIST's maximum time-averaged radiated emission is more than 1000 times *weaker* than the typical RF broadcast, even without accounting for the considerable bandwidth difference of a factor of 10-1000.

3.2.4.2. FIST's peak RF transient emission is more than 30,000 times *weaker* that from a lightning stroke.

3.2.4.3. Conclusion: FIST's radiated output is significantly lower, by at least a factor of 1000, than manmade CW broadcast source and natural RF transients.

4. Operation & Maintenance

4.1. Setup

4.1.1. Identify a dry and preferentially elevated (from the ground) location near the DUT. Avoid moisture or condensation. Avoid tall obstructions that may block the sky view and GPS reception. Place the FIST case flat and open as shown in Figures 1 and 2.

4.1.2. Inventory the following connections, interfaces and switches:

4.1.2.1. 120V power cord. This is used to charge the GPS receiver's internal battery while indoors. Typical outdoor operation does not use the facility power.

4.1.2.2. The main power switch on the front panel (FP).

4.1.2.3. GPS antenna and connection on the GPS receiver (TNC) on the back panel (BP).

4.1.2.4. Coax trigger cable between the GPS receiver (BNC) and the pulser (SMA).

4.1.2.5. EM pulse coupling cable.

4.1.3. Make the following connections:

4.1.3.1. Connect the GPS antenna to the receiver (TNC).

4.1.3.2. Connect the coax trigger cable (BNC-SMA). Standard operation uses the GPS receiver's 1PPM output on the BP.

4.1.3.3. Connect the electrical pulse coupling cable.

4.1.3.3.1. Insert the coupling screw into the pulser's output port at the top of the red dome.

4.1.3.3.2. Use the alligator clips to attach the coupling cable to the pulser at one end and DUT's grounding point at the other.

4.1.3.3.3. The coupling cable can snake but should not touch itself. It also should not touch other conductive or wet parts or surfaces.

4.1.4. Connect DC power cable at the pulser

4.1.4.1. FIST's GPS receiver's internal battery also powers the pulser through a DC power cable.

4.1.4.2. Standard FIST units (FIST3 and after) do not have a power switch on the BP or the pulser. Instead, the pulser's on/off is controlled by inserting/extracting the power plug to the GPS receiver BP's +12V jack.

4.1.4.3. Older FIST units (FIST1 and FIST2) have power switch(es) on the EM pulser and/or on the back panel. This description is provided for completeness only. Non-FIST team users should not see this configuration.

4.1.4.4. At setup, connect only the DC power cable to the pulser. The pulser's actual power on is done at step 4.2.5.

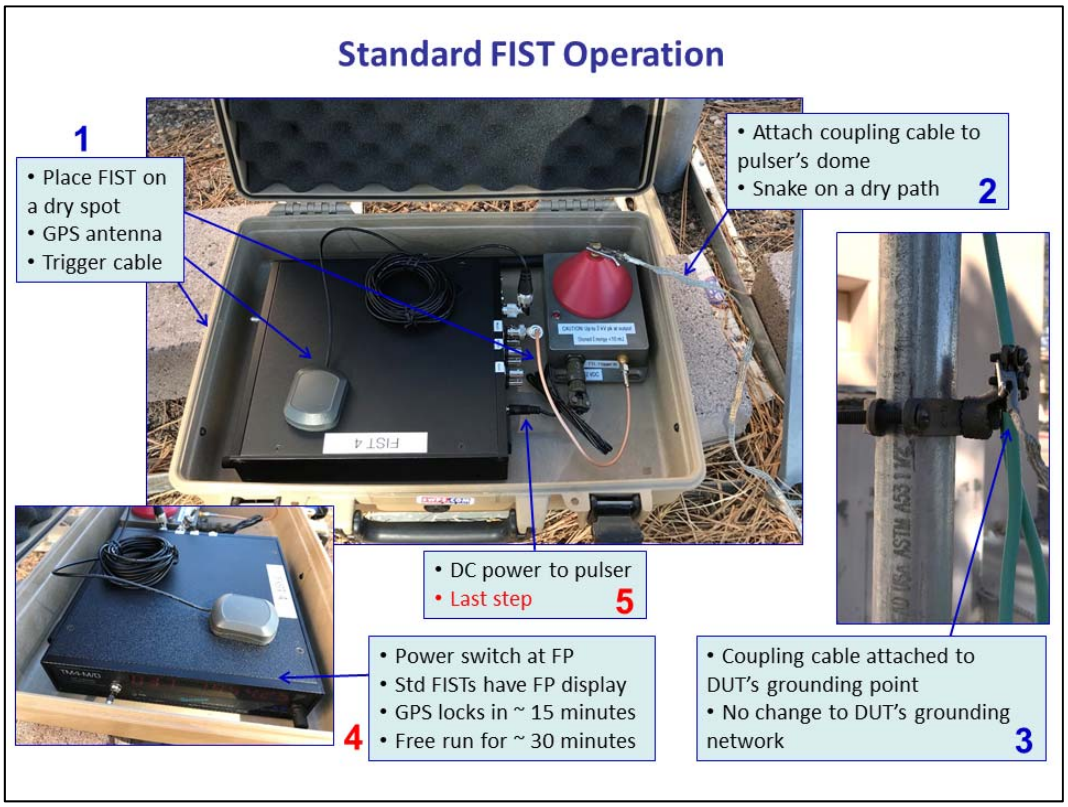

Figure 2. Typical FIST operation configuration.

4.2. Operation – (On/Ops/Off)

4.2.1. Perform a final check the connections and confirm that the pulser is power off (see 4.1.4).

4.2.2. GPS Power on: Turn on the power switch on the GPS receiver's FP.

4.2.3. GPS timing quality check

4.2.3.1. Standard FIST units have a FP display with an intensity control knob on the right. Adjust the knob for display visibility.

4.2.3.2. The display will indicate the GPS timing status, starting with 888:88:88:88 which indicates that the receiver is not synchronized. It is not useful for timing.

4.2.3.3. Once FIST receives the almanac, the FP display begins to show meaningful numbers in UTC as DOY:HH:MM:SS. The display will advance once per second (PPS). FIST timing is good enough for use from this point forward, with performance improving over time. If desired, dim the display after the GPS achieves usable timing to conserve battery life.

4.2.3.4. FIST1 has no display. The FP LED lights are used to determine its GPS timing quality and lock status. Usable GPS timing is indicated by the absence of red light at lower right corner. GPS phase lock is indicated by two solid blue lights.

4.2.4. The GPS receiver's time to first fix (TTFF) depends on many factors: from a few minutes to teens of minutes, with 15 minutes being typical TTFF for a cold start. If the GPS fails to achieve usable timing after 30 minutes, turn off the power and contact the FIST team.

4.2.5. After GPS achieves usable timing, turn on the pulser with the following steps.

4.2.5.1. Power on the pulser by making the DC cable connection on the receiver's BP (see 4.1.4). Check the pulser's power indicator light.

4.2.5.2. Let FIST free run for the desired duration. Typically 30-60 minutes. A fully charged FIST's battery should provide 2+ hours operation. Budget the operation accordingly.

4.2.5.3. If outdoor AC power is available and assessed to be safe, using the 120V AC power will keep the FIST charged and operating indefinitely.

4.2.6. Power off and safing

4.2.6.1. Turn off the master power on the GPS receiver FP, which turns off everything.

4.2.6.2. Disconnect and store all interface cables and parts.

4.3. Stowing, Shipping & Maintenance

4.3.1. All FIST parts should fit into the carrying case. Take care to provide ample padding for stowing or shipping. Pay special attention to protect the GPS receiver's FP power on/off toggle switch. Make sure that the cables are not crimped or damaged when closing the case.

4.3.2. The FIST's GPS receiver contains a sealed lead acid battery.

4.3.2.1. DOT regulation allows for the shipping of these batteries while holding charge. It is the user's choice whether to totally discharge the battery for shipping.

4.3.2.2. The exterior of the shipping container should have a clear label of "Non-Spillable Battery": all FIST brief cases have been labeled.

4.3.2.3. If the carrying case is put inside a bigger container, make sure that the outside container also has a "Non-Spillable Battery" label.

4.3.3. Interface connections:

4.3.3.1. It is highly advisable that all interfaces cables should be disconnected and protected for shipping.

4.3.3.2. When transporting by hand or within a city area, it's the user's choice regarding the state/condition of the interface connections. Exercise best judgment.

4.3.4. When not in use, FIST should be stored indoors and at room temperature.

4.3.5. FIST's internal battery is charged through the AC power. Some GPS solution parameters are maintained by a separate smaller battery. The main battery can help maintain the charge in the smaller battery. Whenever practical, the GPS receiver should be kept in a fully charged state: this not only ensures FIST's short-notice availability, but also prolongs the battery's life.

4.3.6. The GPS receiver's internal battery has a finite lifetime. Recommended battery refresh period is 2 years, or whenever there is a sign of battery life degradation. The battery replacement should be done by experienced personnel with the part Powersonic PS1229. Dispose of the old battery following proper procedures.